

CHIRONOMID (DIPTERA: CHIRONOMIDAE) LARVAL OCCURRENCE AND TRANSPORT IN A MUNICIPAL WATER SYSTEM¹

E. C. BAY

*Washington State University, Research and Extension Center
Puyallup, WA 98371-4998*

ABSTRACT. Chironomid larval populations contaminating a municipal water system were monitored over a 24-month period between June 1987 and June 1989. Larval drift within distribution lines occurred throughout the year, and larval suspension was uniform at all depths within open reservoirs. Draining and cleaning reservoirs to rid them of chironomid populations was of questionable value because larval populations recovered fully within weeks, and larval drift occurred throughout the system.

INTRODUCTION

Chironomid midge larvae in potable water constitute an aesthetic nuisance, but not a public health problem. Larvae have never been found to be disease vectors, or otherwise injurious to man (Gerardi and Grimm 1982, Ali 1991). These larvae, however, can cause serious public relations concerns for municipal water suppliers. Such an incident occurred in the city of Tacoma, WA, in the fall of 1986, when a prisoner in the city's new jail found a red "worm" in his drinking water.

All but 2 of Tacoma's 5 city reservoirs are now enclosed, but in 1986, the system was entirely open. Complaints of larvae in Tacoma's tap water have historically averaged 4–6 per year. Prior to this study, the standard response of the water department to larval complaints was to drain and scour the suspected source reservoir. The jail incident prompted the city of Tacoma to commission this research to determine the magnitude of the problem, identify and evaluate source reservoirs, and recommend possible preventive measures against larval encounter.

MATERIALS AND METHODS

Three primary midge larval monitoring procedures were employed over a 24-month period between June 1987 and June 1989. These included bottom sampling, larval drift and strata sampling.

Four reservoirs were initially selected for this study, but sampling in one, Alaska Street Reservoir, was discontinued in July 1988, when it was dismantled for reconstruction as an enclosed tank reservoir. Others included McMillin, a

3-basin, 757,000-kl lead distribution reservoir, Portland Avenue, and North End reservoirs. All were of complete concrete construction, approximately 7 m deep, with sloping 30° sides surrounded by 1 m-high safety barriers (Fig. 1A). In addition, a system of wires, several meters apart, was installed over each reservoir to discourage bird activity. Bottom sediments rarely exceeded 1 cm deep. These features precluded the use of conventional dredges and bottom sampling techniques.

Standing larval populations were monitored in 2 ways. One was by sets of tethered, submerged, sampling plates designed to monitor larval colonization by tube formation, and the other was by dragnet. Plates were 15 cm² placed uniformly in sets of 4 around each reservoir perimeter approximately 3 m beyond the water's edge. Plates were cut from a cement-like sheet of Flexboard® (Johns Manville Corp.) and marked with a 28-mm grid to facilitate larval and tube counts. Plates were inspected and replaced weekly.

Weekly bottom tows were made with a custom-designed, 500-μm pore mesh, dragnet preceded by a weighted 500-g square frame of spiral nylon brushes (Fig. 2). The 15-cm² net opening collected larval-containing sediments dislodged by the advancing contact brush. Samples were regarded as spatially and seasonally relative, rather than absolute. Four tows were made at each reservoir in the vicinity of the tethered plates previously mentioned. Tow samples were made by casting the net apparatus for a distance of 10 m, then retrieving it as a drag for 3 m. At 3 m the net was jerked off of the bottom and recovered. Samples were concentrated into 120-ml volumes of reservoir water for transport.

In the laboratory, 0.5 g of NaSO₃ was added to each sample for 5–10 min to distress larvae into evacuating their feeding tubes. Larvae were then simultaneously stirred and bubbled into suspension, from which one 20-ml aliquot was

¹ This research was supported in part by a grant from the city of Tacoma, WA, Public Utilities Water Division.

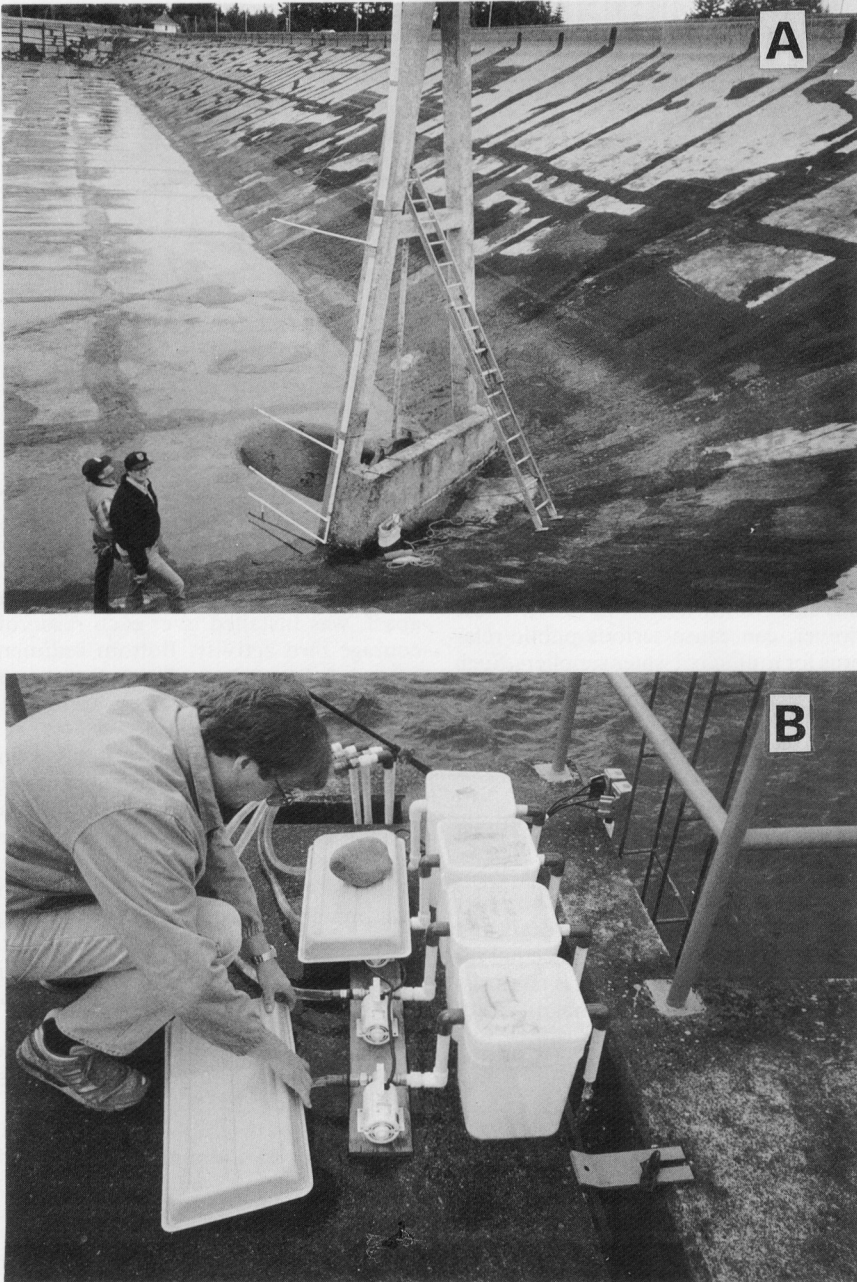


Fig. 1. Portland Avenue Reservoir. A. Strata sample intake installation (horizontal pipes extending from vertical structure); B. Strata collection pumps and receptacles.

drawn per sample. Larvae were identified and counted by aid of a binocular dissecting microscope.

Larval drift: Larval drift, the transport of larvae within distribution lines, was measured in relation to kiloliter flow by running tap water

through a collection device (Fig. 3) at a rate of 6 liters/min, or 60 kl/wk for approximately 1-wk intervals. The collection device consisted of 2 receptacles connected by a 50-cm length of 2-cm diam polyvinyl chloride (pvc) pipe with a downward-pointing elbow at each end. The primary

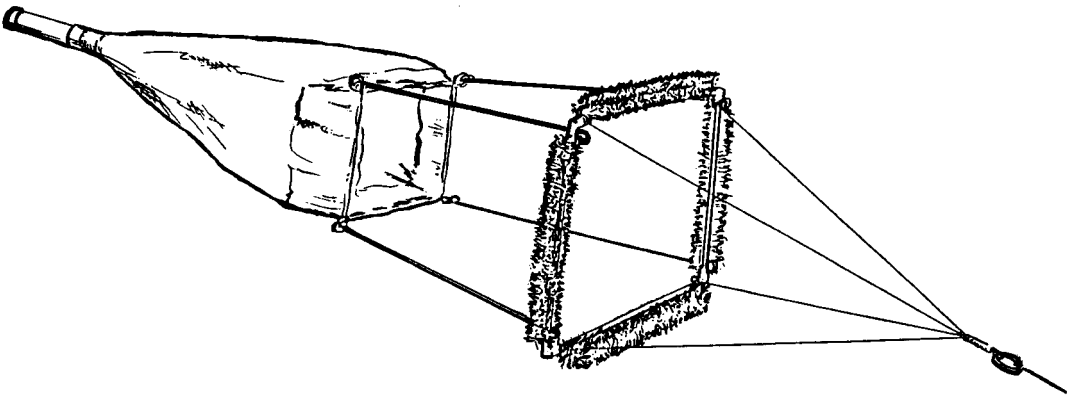


Fig. 2. Dragnet for collecting benthos from concrete surfaces. The weighted brush dislodges sediments in advance of the net opening.

receptacle was a 100-liter vinyl barrel, and the secondary receptacle was a 21-liter covered plastic food storage container. The primary overflow guard was a 500- μ m pore mesh, 14-cm wide, submerged screen through which water entered from beneath. This configuration evenly distributed filtrate, reduced overflow velocity, and pre-

vented larvae from concentrating against and working through the mesh. Collected larvae were almost always alive, or at least intact. Overflow to the secondary container was filtered through a submerged, finer mesh bag made from a section of woman's nylon stocking. Water discharged to waste through a floor drain. Upon weekly col-

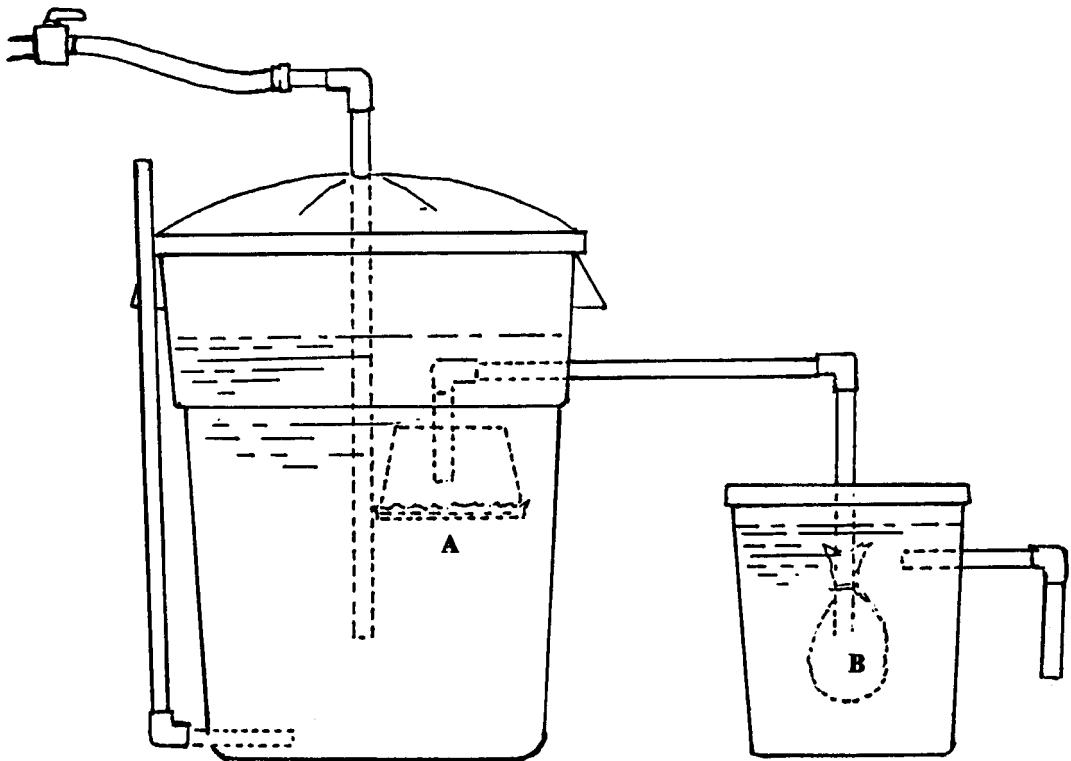


Fig. 3. Drift collection device. Most adrift larvae are retained in the primary receptacle (barrel) by an inverted, submerged, overflow screen (A). Pass-through larvae are captured by a submerged filter bag (B).

lection, both the overflow screen and the secondary mesh bag were rinsed into the primary receptacle, and the contents were then emptied through a tilt-standpipe drain onto a submersed concentrating sieve.

Larval drift was monitored at 4 Tacoma sites, which included the chlorinator plants at McMillin and Portland Avenue reservoirs, a tap off of the distribution line near Hood Street Reservoir, 16 km downstream from McMillin Reservoir, and 10 km beyond that, the Marine View Drive Pump Station. Larval drift for these locations was monitored for a minimum of 3 months, from August to October 1987, at Hood Street, and a maximum of 21 months, from July 1987 through April 1989, at McMillin Reservoir. In addition, during the summer of 1989, single 1-wk collections were made for each of 5 different municipal water systems between Olympia and Bellingham, WA.

Strata sampling: Larval uptake for different water depths was monitored, in 1988, over 3 and 7 months for McMillin and Portland Avenue reservoirs, respectively. Monitoring was accomplished by a system of pumps and manifolds constructed with 2-cm pvc pipe attached to service platforms within each reservoir (Fig. 1B). Each manifold had 4 separate intakes, each with delivery controlled by a dedicated centrifugal pump. Pumps were attached to collection units similar to the secondary receptacles of the drift monitoring apparatus previously described. These were located upon the service platforms above the reservoir. Intakes were oriented horizontally, one above the other, at depths of 15, 45, 135 and 405 cm from the reservoir floor. Intake openings were guyed 3 m outward from platform scaffolding to prevent the scaffolding from serving as a confounding larval source. Twenty-four hour pump collections were made at varying day intervals commencing with reservoir postcleaning refill. Pump delivery was 0.875 kl/h. All larval collections were transported to the laboratory for counting and identification.

RESULTS

Standing larval populations: Sampling plates for assessing standing larval populations proved to be of limited value. Only occasionally were they well colonized with easily discernable larvae and tubes. More often plates were obfuscated by periphyton and a combination of inhabited and vacated early instar larval tubes too numerous and fragmented to count. Sampling plate data are, therefore, not included here.

Bottom tows were very reliable, and standing larval populations were recorded in excess of

6,000 larvae/m² (Fig. 4). Densities varied both within reservoir and year. Species composition varied among reservoirs, years and seasons.

Three species of larvae dominated all collections (Figs. 4 and 5). The most conspicuous species was *Conchapelopia americanus* Fittkau, a relatively large, 4–6 mm, tanypodine larva. The most numerous larvae in all reservoirs were usually small, <3 mm long, *Psectrocladius* species. *Paralauterborniella subcincta* (Townes), the 3rd species, was common during the cooler months of late fall through early spring and completely replaced *Psectrocladius* as the dominant larva in McMillin Reservoir between late November 1988 and early June 1989. Other less frequently encountered larvae included *Tanytarsus* sp., *Phaenopsectra profusa* (Townes), *Micropsectra* n.sp. and *Cricotopus* sp.

Standing larval populations comprising mostly *Psectrocladius* spp. were maximum for each reservoir during August, with 1987 peaks ranging from 1,700 to 5,600 larvae/m² for Alaska Street and Portland Avenue reservoirs, respectively. During 1988, the same August pattern prevailed but with peaks of 800 and 6,800 larvae/m² for North End and Portland Avenue reservoirs. Alaska Street Reservoir was discontinued at the time because of reconstruction. In McMillin Reservoir, peak August larval density comprised mostly *Psectrocladius* spp., and ranged between 1,500 and 2,500 larvae/m² in both 1987 and 1988.

Spring reservoir cleaning appeared to have little influence on seasonal larval population peaks. Portland Avenue Reservoir, cleaned March 1, 1988, recorded 1,000 larvae/m² within 18 wk in early July, compared to 10 wk postcleaning for McMillin Reservoir, which was refilled May 24, and indicated 1,000 larvae/m² by August 3. Larvae in North End Reservoir, which was cleaned on May 2, 1988, never measured more than 800 larvae/m², and except for a very brief period in October, seldom exceeded 100 larvae/m² throughout April 1989.

Peak larval populations, in 1988, exceeded 2,000 larvae/m² for Portland Avenue Reservoir, and slightly more or less than 2,000 for McMillin Reservoir into mid-September. During 1987, both Alaska Street and North End reservoirs, cleaned and refilled May 27 and June 8, respectively, attained 1,000 larvae/m² by mid-August. Both McMillin and Portland Avenue reservoirs exceeded these populations even earlier.

Drift: Larval drift proved to be a constant phenomenon at all locations (Figs. 6 and 7), but was characterized by different numbers and species ratios. Mean drift rates for various locations ranged from a high of 4.73 larvae/kl for Marine View Drive pump station in 1987, to a low of

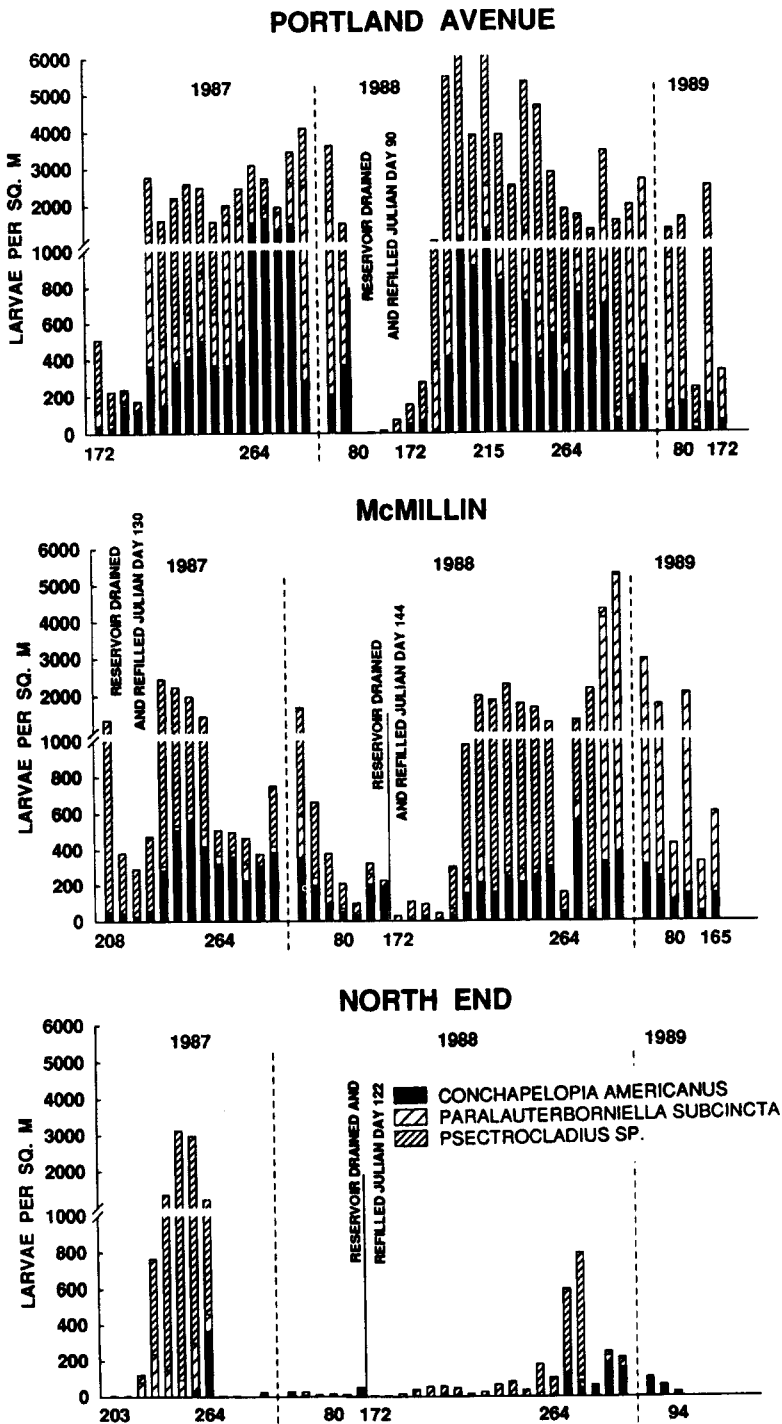


Fig. 4. Population densities by Julian days of benthic chironomid larvae in 3 Tacoma City reservoirs between June 1987 and June 1989.

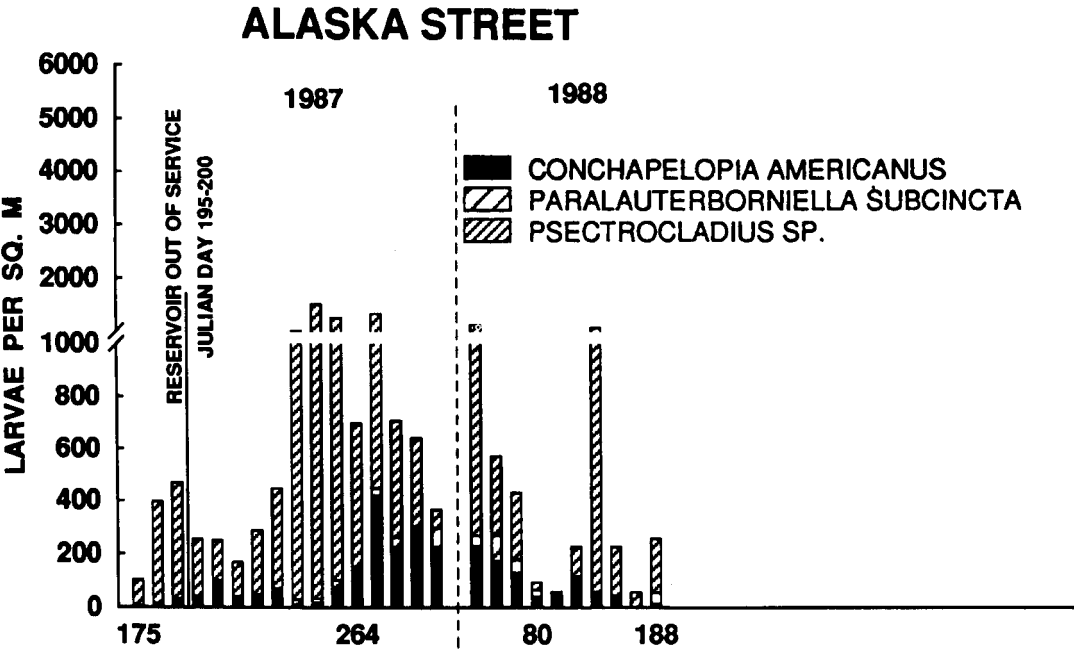


Fig. 5. Population densities by Julian days of benthic chironomid larvae in Alaska Street Reservoir, Tacoma, WA, in 1987 and 1988.

0.60 for the same location in 1988 (Table 1). The highest recorded drifts, mostly *Psectrocladius* spp., up to 11.5 larvae/kl, occurred at the Marine View Drive pump station during late August

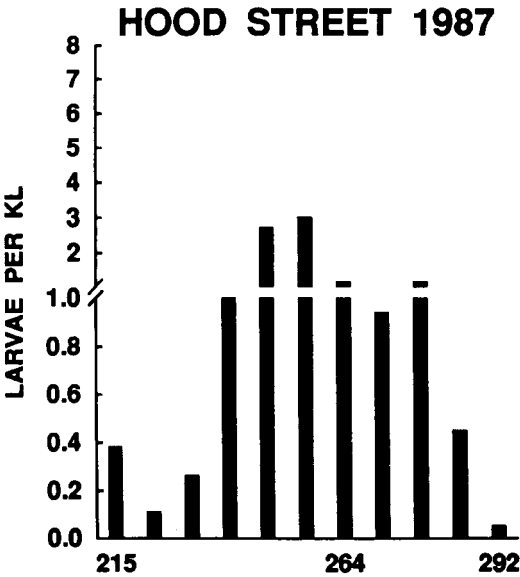


Fig. 6. Chironomid larval drift interception at 3 tap locations as recorded by Julian days, Tacoma, WA, 1987-89.

through September 1987 (Fig. 7). Drift for the same location and period during 1988 did not exceed 0.2 larvae, and the highest earlier incidence, on July 6, was less than 4 larvae/kl. In comparison, larval drift for McMillin Reservoir, almost exclusively *C. americanus*, was highest during April 1988, when it ranged from 4.2 to 5.8 larvae/kl, and in October 1987 never exceeded 3.3 larvae. Peak larval drifts for other locations were Portland Avenue Reservoir, 6.3 larvae (mostly *Psectrocladius* spp.) in early July 1988, and Hodd Street Reservoir, 2.7-3.0 larvae in September 1987.

Isolated 1-wk drift collections for other western Washington water systems ranged from 0 for the cities of Puyallup, Bellingham, and Everett, to 0.05 and 0.10 larvae/kl for the cities of Seattle and Olympia, respectively. Both Bellingham and Everett have filtered water systems. Samples for all sites except Salmon and Maple springs, Puyallup, contained minute quantities of insect contaminants, including exuvial and adult remains of various aquatic insects. Puyallup's spring system is enclosed storage. The single sample from McCallister Springs, Olympia, also contained a meager collection of copepods, ostracods and hydracarina.

Strata distribution: One or more pumps failed during the collection period on several occasions. However, 8 successful collections (24-h uptakes)

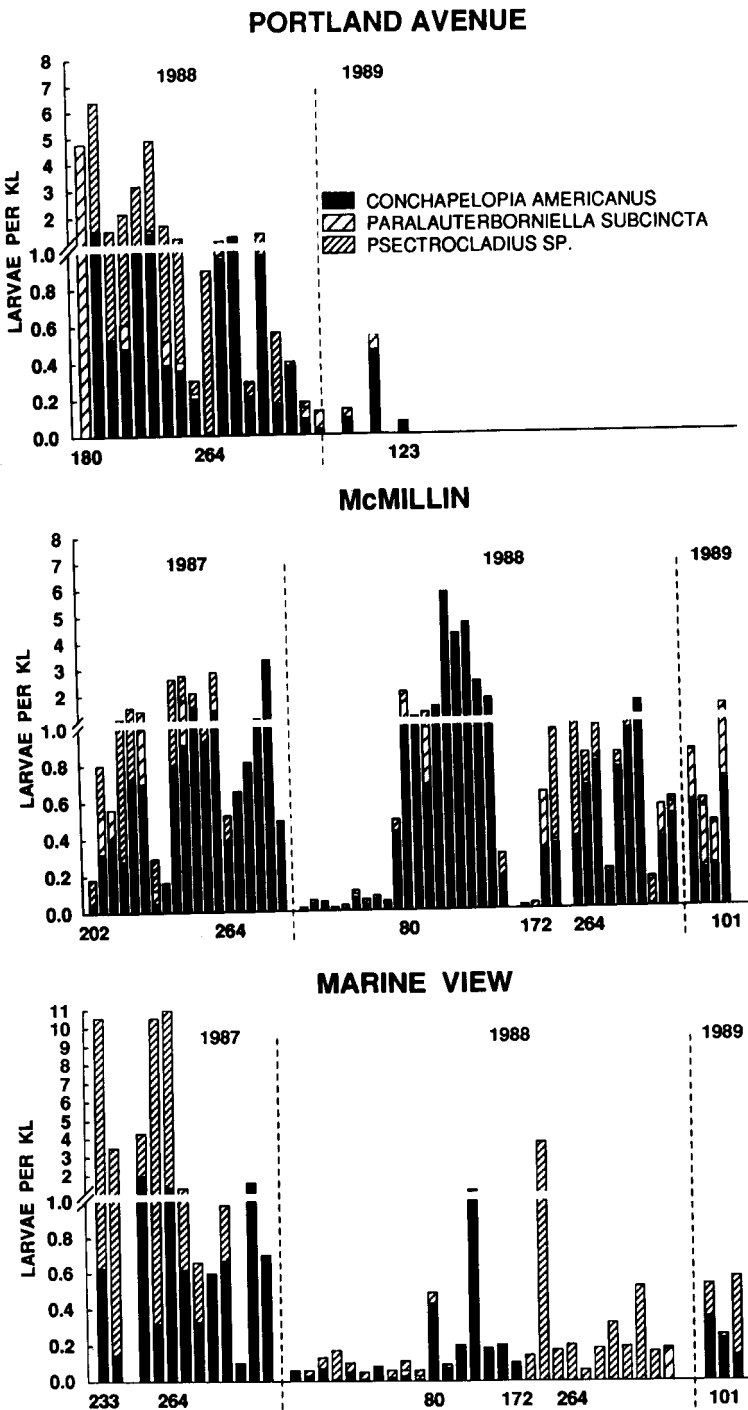


Fig. 7. Chironomid larval drift interception as recorded by Julian days, Hood Street Reservoir, Tacoma, WA, 1987.

Table 1. Mean chironomid larval drift expressed as larvae/kl and determined by flow interception at 3 collection sites, Tacoma, WA, 1987 and 1988.

	McMillin Reservoir		Marine View Drive		Portland Avenue
	1987	1988	1987	1988	1988
<i>n</i>	19	35	14	31	18
$\bar{x} \pm SD$ larvae/kl	1.50 \pm 1.02	1.08 \pm 1.41	4.73 \pm 4.46	0.60 \pm 0.83	2.20 \pm 2.28

were made for each depth stratum at Portland Avenue Reservoir, and 10 for each stratum at McMillin Reservoir, except for the 135 cm depth, which had 11 collections. Larvae occurred at all strata on all occasions with analysis of variance showing no difference at the $P = 0.5$ level (Table 2). As with bottom samples and drift, larvae did vary in species and magnitude for time and location as shown in combined strata collections (Fig. 8). The predominant species were, as with bottom and drift collections, *Psectrocladius* and *C. americanus*.

DISCUSSION

The most significant findings of this study were the degree of chironomid productivity in the reservoirs, the amount and frequency of larval drift, and the even distribution of pelagic larvae throughout reservoir profiles. With these findings it might seem surprising that complaints about larvae are not more frequent than occur. That they are not is partly due to the minute size, translucence, and pale coloring of most specimens, and more importantly, the way in which we use our water. The greatest likelihood of observing a contaminant larva is in a drinking cup, a glass or an enamel basin. The quantities of water so viewed are minuscule compared to those used for bathing, laundry, cooking, gardening, pools and industry. Assuming a drift rate of 1

larva/kl the chances of encountering a larva in a given 200-ml cup of water would be 1 in 5,000, and then only if one was observant.

Magnitude of problem: Although there is substantial literature on the biology, systematics, ecology and control of midge flies of the family Chironomidae in most aquatic habitats (Ali 1991), few accounts occur for potable water distribution systems (Smalls and Greaves 1968,

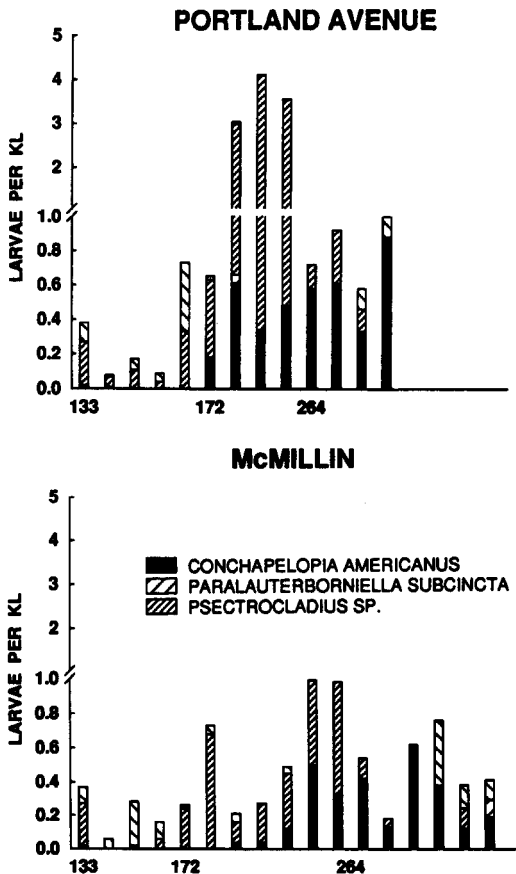


Fig. 8. Chironomid larvae/kl for all strata by Julian days in each of 2 reservoirs. Shown are 24-h uptakes following reservoir filling in May 1988, and continuing through December 1988.

Table 2. Mean number of chironomid larvae/kl by strata for McMillin Reservoir (in service as of March 5, 1988) and Portland Avenue Reservoir (in service as of May 24, 1988).

		Depth (cm)			
		15	45	135	405
McMillin	<i>n</i>	10	10	11	10
	\bar{x}	0.38A ¹	0.54A	0.39A	0.24A
Portland	<i>n</i>	8	8	8	8
	\bar{x}	1.36A	1.07A	1.03A	0.84A

¹ Horizontal values followed by the same letter are not significant at the $P = 0.5$ level.

Mitcham and Shelley 1980, Gerardi and Grimm 1982, Seppanen 1982). The most definitive work on Chironomidae in water storage reservoirs concerns the distribution and seasonal changes of the chironomid fauna of 2 English reservoirs between 1950 and 1953 (Mundie 1957). These reservoirs differed from those in Tacoma, however, in that they had mud bottoms and supported a complex population of flora and fauna.

Encounter of midge larvae in domestic water is less rare than might be presumed from the scientific literature, including water trade journals (Rickards 1943, Flentje 1945). Most instances go unpublicized, or occasionally, as happened with the Tacoma jail incident mentioned earlier, are restricted to local news media. Another occurrence made local headlines in Annapolis, WA, in October 1989, when customers of an independent water company experienced repeated larvae. While working in California, I consulted in several such incidents, including one from an enclosed LaCienega reservoir. This reservoir had become contaminated during a sand filter backwash with larvae-infested water. Established larvae emerged to mate and reproduce.

Most chironomid mating is associated with aerial swarming, for which enclosed reservoirs would not seem conducive. I have, however, observed terrestrial mating by males walking up to females for a variety of species on several occasions. Parthenogenic chironomid infestations in water systems have been reported by Krueger (1941) and Williams (1974). Stenogamous species have also been maintained in laboratory culture (Biever 1965). Reservoir enclosure, as noted above, is not a guaranteed solution to midge larva contamination. Other reports of midge larvae in enclosed reservoirs and distribution systems include Wilhelmi (1925) and Smalls and Greaves (1968). Enclosure does, however, protect against airborne dust and particles, which contribute to larval nutrition.

In 1988, a few sparse CDC light trap collections of emerged midges were taken within Tacoma's newly enclosed Hood Street Reservoir. It was never determined whether a sustaining population developed within this or other reservoirs that were later covered. No midge larvae were reported by Tacoma water users in 1991, and only a single complaint was received in April of 1992. In April 1993, however, several complaints were received from a single localized area.

Of particular interest was the difference in chironomid midge productivity and encounter for open reservoir systems in the major northwest metropolitan areas of Seattle, Tacoma and Portland, OR. According to city of Seattle water department personnel who we visited in June 1987, Seattle experiences similar problems with its open

reservoirs as does Tacoma, and with approximately the same frequency. Visual inspection of bottom samples taken in June 1987 from Seattle's South Spokane Street Reservoir indicated sediments and larval populations comparable to those in Tacoma's reservoirs. Seattle lies approximately 50 km north of Tacoma, and takes its water from the Cedar River. Tacoma's open water source is the Green River.

Curiously, the city of Portland, OR, 240 km south of Tacoma, with 2 major open water reservoirs, reportedly does not have a midge problem. This was confirmed by a visit on April 21, 1989, during which several sample drags taken from both Mt. Tabor and Washington Park reservoirs yielded a total of only 11 larvae. These reservoirs were at the time overdue for cleaning on a 6-month schedule, but were nearly free of sediment.

Reasons for the productivity differential between the city of Portland's reservoirs, and those of Tacoma and Seattle are not known, but are suspected to be at least partly due to logging practices. Portland's watershed has historically been unlogged, and Seattle's Cedar River watershed logged only moderately. Tacoma's Green River watershed, by contrast, has been severely clear-cut. Clearcutting contributes substantially to water runoff and sediment distribution.

The lack of sediments in Portland reservoirs also suggests that there may be less airborne siltation than for Seattle and Tacoma, but this was not measurable. Reasons for the atypical character of Tacoma's previously uncovered, terminal, North End Reservoir, when compared with other Tacoma Reservoirs remain equally obscure.

Preventive recommendations: Although other factors may be contributing, it would appear, with the general decline in larval complaints, that enclosing 3 out of 5 Tacoma city reservoirs has largely solved that city's midge larva problem. Yearly population variation, however, cannot be wholly discounted. Although McMillin Reservoir, still uncovered, has not been sampled since 1990, resident service workers report that adult midge activity has been noticeably less than in previous years. The absence of spider webs, midge remains, and spotting of structures supports this observation.

The purpose of stratification studies was to determine whether larval intake might be influenced by modifying the elevation of reservoir outfalls. Uniform pelagic larval distribution indicates that it cannot be influenced.

Reservoir cleaning during active midge breeding in spring and summer is of temporary value. Ali et al. (1976), working with concrete-lined flood control channels in southern California, found

that cleaning provided satisfactory midge control for only 2 wk.

Faucet filter screens and aerators were investigated and found to be ineffective as larval barriers. Early instar chironomid larvae passed readily through these when applied in water suspension from a syringe.

Enclosing and/or filtering municipal reservoirs appears now to be the most practical and efficient, if imperfect, means of reducing complaints about midge larvae from water users. Complaints of occasional larvae will undoubtedly continue to occur. Most of these, however, can be quietly and successfully handled with a simple factual explanation.

REFERENCES CITED

- Ali, A. 1991. Perspectives on management of pestiferous Chironomidae (Diptera), an emerging global problem. *J. Am. Mosq. Control Assoc.* 7:260-281.
- Ali, A., M. S. Mulla and F. W. Pelsue. 1976. Removal of substrate for the control of chironomid midges in concrete-lined flood control channels. *Environ. Entomol.* 5:755-758.
- Biever, K. D. 1965. A rearing technique for the colonization of chironomid midges. *Ann. Entomol. Soc. Am.* 58:135-136.
- Flentje, M. E. 1945. Elimination of midge larvae with DDT. *J. Am. Water Works Assoc.* 37:1053.
- Gerardi, M. H. and J. K. Grimm. 1982. Aquatic invaders. *Water Eng. Management* 10:22-23.
- Krueger, V. F. 1941. Eine parthenogenetische Chironomide als Wasserleitungsschadling. *Naturwissenschaften* 36:556-558.
- Mitcham, R. P. and M. W. Shelley. 1980. The control of animals in water mains using permethrin, a synthetic pyrethroid. *J. Inst. Water Eng. Sci.* 34:474-483.
- Mundie, J. H. 1957. The ecology of Chironomidae in storage reservoirs. *Trans. R. Entomol. Soc. Lond.* 109:149-232.
- Rickards, J. C. 1943. Overcoming a bloodworm (chironomid) problem. *Public Works Mag.* 74:11-38.
- Seppanen, H. 1982. Microbiology of drinking water: organisms in filters and the distribution network. *Vesitalous* 23:24-29.
- Smalls, I. C. and G. F. Greaves. 1968. A survey of animals in distribution systems. *J. Water Treat. Exam.* 17:150-183.
- Wilhelmi, J. 1925. Zuckmuckenlarven in Hochbehälter einer Wasserverorgansanlage. *Kl. Mitt. Mitgl. Ver Wasserversorgung Abwasserbes.* 1:119-120.
- Williams, D. A. 1974. An infestation by a parthenogenic chironomid. *J. Water Treat. Exam.* 23:215-229.